GSA

2021

GPG Validated Technologies

Green Proving Ground evaluates next-generation building technologies in real-world operational settings. Below you'll find testbed results for technologies with deployment potential in GSA's real-estate portfolio. Note that payback and performance are site-specific and will vary. Also, since the testbed results were published, prices may have changed and there may be other comparable technologies that meet performance specifications.

» Building Envelope

» Lighting

» Energy Management

» Renewables

» HVAC

» Water

» Limited GSA Potential

The Center for Emerging Building Technologies' two programs, Green Proving Ground (GPG) and Pilot to Portfolio (P2P), enable GSA to make sound investment decisions in next-generation building technologies based on their real-world performance.

Updated: November 2021
Additional resources: **www.gsa.gov/gpg**

2021

Building Envelope

EC Windows for Land Ports of Entry

Best suited to facilities where window glare compromises mission-critical outdoor visibility.

EC Windows for Office Space

Best suited to facilities where outside views are critical. EC glass can also enhance architectural features that provide a connection with the outdoors, such as skylights and atriums, though this was not evaluated.

High-R Window Retrofit System

Best suited to single-pane windows in cold climates.

Lightweight Quad-Pane Windows

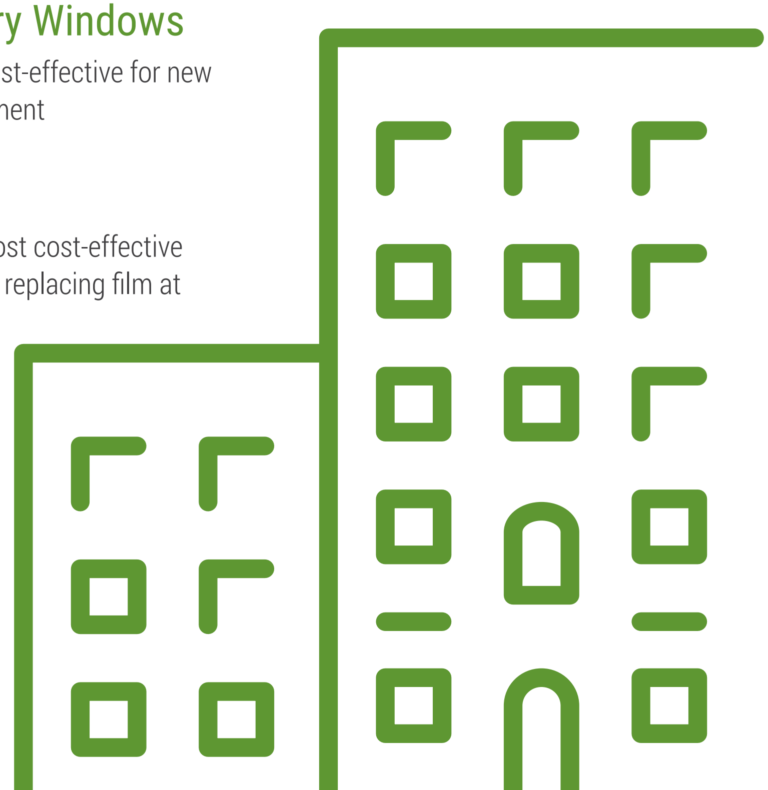
Suitable for all climate zones. Cost-effective for new construction or window replacement

Lightweight Secondary Windows

Suitable for all climate zones. Cost-effective for new construction or window replacement

Low-e Window Film

Suitable for all climate zones. Most cost-effective for single-pane clear windows or replacing film at end-of-life.



M&V results demonstrate broad deployment potential for GSA

2014

EC Windows for Land Ports of Entry

Best suited to LPOE and other facilities where window glare compromises mission-critical outdoor visibility.

Description & Lessons Learned

- In response to a small amount of applied voltage, EC windows transition through variable tint levels to optimize daylighting while reducing glare and solar heat gain.
- Automatic transitions based on photosensor readings and sun path calculations protect from glare without the need for window blinds.
- EC windows should be considered for Land Ports of Entry (LPOE) and other facilities where it is important to maintain unobstructed visual contact with exterior surroundings under glary, sunny conditions.

Installation

- Testbed added custom-built, hinged, framed EC windows to existing windows, to reduce cost and preserve warranty of exising bulletproof building components.

O&M

- Window tint control system operates automatically, manually, and by BAS input.

Occupant Satisfaction

- 100% of survey respondents said they would choose EC windows over conventional windows.
- EC windows may reduce nighttime visibility due to increased interior-facing reflectance.
- EC may be less effective in controlling glare on bullet- and blast-resistant EC insulated glass unit (IGU) and on structures without deep overhangs.

Deployment

- Retrofit, new construction
- Product tested: SageGlass

Testbed Energy Savings

N/A

Testbed Cost Effectiveness

\$45/ft² with existing frame
(not bullet or blast resistant)

Tech life: 30 yrs

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EC Windows for Office Space

Best suited to facilities where outside views are critical. EC glass can also enhance architectural features that provide a connection with the outdoors, such as skylights and atriums, though this was not evaluated.

Description & Lessons Learned

- In response to a small amount of applied voltage, EC windows transition through variable tint levels to optimize daylighting while reducing glare and solar heat gain.
- With a single facade, use zones to limit gloominess; either add a daylight zone of IGUs above, or control individual windows independently.
- A blue tinted layer of glass was added in Portland to match the existing facade. This limited the window switching range. Select EC windows with a clear inboard glass layer.
- The mulitple zone control with SageGlass was challenging to program.

Installation

- View Glass installed ahead of schedule with no issues. Sage installation in Sacramento experienced multiple difficulties through these were eventually resolved.

O&M

- At both test beds, substantial post-installation commissioning was required to balance the competing needs of glare control, lighting- and cooling-energy savings, and tenant acceptance. This was particularly true of the multiple tint zones in Sacramento.

Deployment

- New construction or major renovation
- Product tested: View Glass (Portland) SageGlass (Sacramento)

Occupant Satisfaction—Portland

- 85% and 92% of occupants preferred View Glass EC.
- Less glare and no change in thermal comfort. Slow switching speed (20–30 minutes) meant that interior shades were still needed. 40% more blinds were fully raised in EC area compared to original windows in private offices; mixed results in open plan offices.
- Occupants found Tint 4 to be too dark, and this functionality was disabled. They also found Tint 3 to be dark when implemented during the winter. Controls were changed so that in winter months only Tints 1 and 2 were automatically used. Occupants rarely overrode settings once automatic control was modified.
- Some of the issues occupants reported with EC windows, such as the time the glass took to achieve full tint, may have impacted occupant satisfaction. EC window manufacturers report faster tinting transitions in newer versions.

Occupant Satisfaction—Sacramento

- 60% preferred SageGlass EC windows.
- 79% of the blinds were lowered from their fully raised position. Blind use may have been impacted by the fact that the windows were not functioning properly for 7 months before a manufacturing defect was discovered and all the windows were replaced. Slight reduction in blind use over the course of the study (90% blinds were lowered at the beginning of the study.)
- A relatively small number of people regularly overrode the automatic settings.

Testbed Energy Savings

Perimeter zone lighting savings:
2.15 kWh/ft²/year

Testbed Cost Effectiveness

Payback:
29 years

SIR:
1

Portland installed cost:
$158/ft²
($78/ft² materials/$73/ft² labor)

Sacramento installed cost:
$240/ft²

Installed cost at mature market pricing:
$61/ft² using existing frame

Tech life:
30 years

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2013

Hi-R Low-e Window Retrofit System

Best suited to buildings in cold climates with single-pane windows.

Description & Lessons Learned

- Improve thermal performance with low emissivity coating; pre-manufactured units, like storm windows, simplifies installation.
- Favorable findings for low investment.
- Site-specific evaluation necessary for optimum results.

Installation

- Quick installation. Pre-manufactured Hi-R panels are installed on top of existing windows and do not require removing or significantly modifying window systems already in place.

O&M

- No impact to O&M.

Occupant Satisfaction

- Improved visual and thermal comfort.

Deployment

- Retrofit
- Product tested: Serious Energy, iWindow; now Thermolite and Berkowitz Renovate

Testbed Energy Savings

41% winter heating energy savings; 11% whole building HVAC

0.017 MBTU/ft²/year

Testbed Cost Effectiveness

Payback: 7 years

SIR: 1.4

Installed cost: $21/ft²

Avg. window replacement cost: $25–$50/ft²

Tech life: 20 (10 year warranty)

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Lightweight Quad-Pane Windows

Suitable for all climates. Cost-effective for new construction or window replacement.

Description & Lessons Learned

- Four panes–two outer panes of low-e glass and either two panes of thin glass or two layers of suspended film– in insulated fiberglass frame with warm-edge spacers and krypton gas.
- Lightweight quad-pane windows are a cost-effective alternative to double-pane windows and offer a real opportunity to improve the building envelope.
- Higher-efficiency windows can reduce HVAC capacity requirements and should be factored into the economics of any new construction or major renovation project.

Installation

- Identical installation to double-pane. Same thickness and comparable weight.
- Suspended-film version offers versatility in low-e coatings, meets tempered glass requirements, and is about 1 lb lighter per square foot than the thin-glass configuration.
- Window configuration should be customized for different climates, particularly the solar heat gain coefficient (SHGC). Windows with a high SHGC collect solar heat more effectively and are more broadly recommended for heating-dominated climates. Windows with a low SHGC block heat gain more effectively and are better suited to cooling-dominated climates.

O&M

- No impact to O&M.

Occupant Satisfaction

- When the outdoor temperature was 21°F, the center of glass temperature of the quad-pane with film was 66°F and the frame was 65°F. The temperature for both the frame and the center of glass in the thin-glass configuration was 65°F.

Deployment

- New construction or window replacement
- Product tested: Alpen High Performance Products

Testbed Energy Savings

24% avg. savings modeled across climate zones

1.7 kWh/ft²/year

Testbed Cost Effectiveness

Payback: 1-3 years

SIR: 8-15

Installed cost: $34.87/ft² quad-pane with thin glass

$36.87/ft² quad-pane with suspended film

$32.387/ft² high-performance double-pane

Tech life: 25

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Lightweight Secondary Windows

Retrofit for single-pane windows.

Description & Lessons Learned

- Thin glass in insulated fiberglass frame. Single & double-pane configurations.
- Pre-manufactured like storm windows.
- 2 to 3 times lighter than inserts manufactured with standard glass

Installation

- Easy installation < 10 minutes for 1 person with no drilled holes or permanent devices.
- Site-specific evaluation is essential to gauging the potential success of secondary window retrofits. Though modeled savings were demonstrated for all building types and climates, performance is highly site-specific..
- Window configuration should be customized for different climates, particularly the solar heat gain coefficient (SHGC). Windows with a high SHGC collect solar heat more effectively and are more broadly recommended for heating-dominated climates. Windows with a low SHGC block heat gain more effectively and are better suited to cooling-dominated climates.

O&M

- No impact to O&M.

Occupant Satisfaction

- Double-pane insert compared to a single-pane window:
  - 20° warmer interior glass
  - 73% reduction in condensation
  - 97% less air leakage
- Both the single-and double-pane inserts reduced infiltration from 2.0 cfm/ft² for a single-pane window to 0.06 cfm/ft². This will result in additional energy savings and accelerated payback, particularly in cold climates

Deployment

- Retrofit for single-pane windows.
- For cold climates, the double-pane secondary window outperformed the single-pane insert and is broadly recommended. For warm climates, a single-pane secondary window with a low SGCH could be more cost-effective.
- Particularly well suited for historic structures where changes to the facade are not allowed
- Product tested: Winsert, Alpen High Performance Products

Testbed Energy Savings

15% avg. modeled whole-building energy savings, double-pane insert with single-pane baseline.

3.3 kWh/ft²/year

Testbed Cost Effectiveness

Payback: 5-11 years

SIR: 2-3

Double-pane insert: $22/ft²

Single-pane insert: $17/ft²

Installation: $1.15/ft²

Tech life: 20

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2017

Low-e Window Film

Suited to all climate zones. Most cost-effective for single-pane clear windows or replacing film at end-of-life.

Description & Lessons Learned

- Combines the solar control functions of a standard applied film with the insulating power of a low-e coating to approximate the performance of double-glazing.
- Appropriate for both hot and cold climates with little variability in climate or facade orientation. Best performance over other applied films considered.

Installation

- Impact on building occupants is minimal.
- Installation requires more squeegee work than other films and requires certified installer with special training.
- VT50 version should be considered for north facing facades and other applications where higher visible transmission is desired.

O&M

- Film needs to be protected from nicks with non-abrasive cleaning; no ammonia-based cleaners or squeegees.

Occupant Satisfaction

- Improved thermal comfort.
- Some dissatisfaction with the color/hue and loss of daylight through north facing windows that previously had no film.

Deployment

- Retrofits, End-of-life replacement
- Product tested: Eastman Chemical, EnerLogic Window Films VT35

Testbed Energy Savings

22% HVAC savings within 15-foot perimeter

Testbed Cost Effectiveness

Payback: 4 years

SIR: 3.3

Installed cost: $7.75/ft^2 (materials $4.25, labor $3.50)

+$1.50/ft^2 removing existing film

Labor costs increases to $5.50–$8.00/ft^2 for divided lights (5ft x 6ft window takes the same amount of time as 1–2 small French panes)

Avg. window replacement cost: $25–$50/ft^2

Tech life: 15 years (warranty)

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2021

Energy Management

» Advanced Power Strips for Plug Load Control

Deploy APS with schedule-based timers broadly.

» Chiller Plant Control Optimization System

Best suited to centrifugal chilled water plants with cooling loads > 3 million tons per year.

» Submeters & Analytics: Full-Panel

Suitable across the portfolio. Most value when monitoring overtime utilities or devices that have high power consumption.

» Submeters & Analytics: Single-Circuit Meter

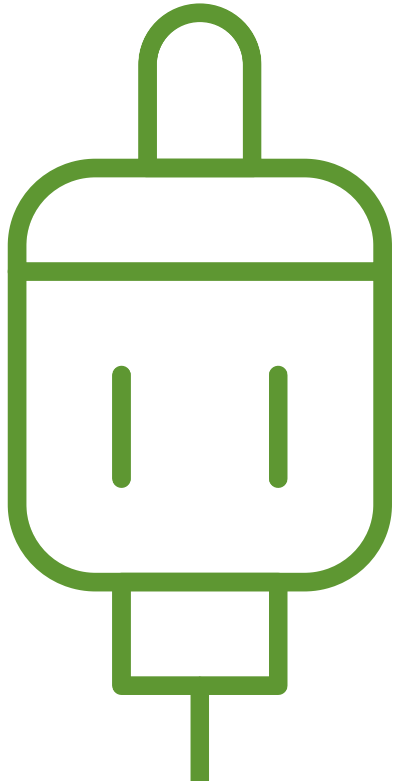
Suitable across the portfolio. Best suited to tenant billing.

» Submeters & Analytics: Wireless CTs

Suitable across the portfolio. Best suited to FDD.

» Wireless Thermostats for Pneumatic Systems

Best suited to facilities with pneumatic control.



M&V results demonstrate broad deployment potential for GSA

Advanced Power Strips for Plug Load Control

Timer-based power strips are suitable for broad deployment.

Description & Lessons Learned

- Power strips de-energize circuits via user and/or system control functionality such as load sensing and schedule timing.
- Simpler and less expensive power strips with schedule-based control, where users determine the day and time when a circuit is energized, were found to be most effective.
- Best strategies match energy use to work schedules.
- Load-sensing strategy was of limited utility. One reason for this is that when applied to kitchens or printer rooms, load-sensing control aggregates power-state data from APSs in surrounding workstations. Because all workstation APSs are monitored in search of a “master” device whose threshold would de-energize auxiliary devices, “slaves” are de-energized only when all workstations are de-energized, which seldom occurs if occupants are present.

Installation

- Quality tech installation is key for load-sensing utility, especially when communicating with a remote server for data storage or control logic.

O&M

- Customizable controls, manual override, and institutional support for user training are key.

Occupant Satisfaction

- Widespread acceptance of timer-based control with user willingness to program their own schedules into an APS.

Deployment

- Retrofits
- Product tested: Enmetric with metering @ $100 each
- Subsequent GSA deployment used timer-based power strips: Belkin, Conserve Surge @ $22 each

Testbed Energy Savings

26% workstation energy savings with advanced computer management already in place

48% energy savings in kitchens and printer rooms

Testbed Cost Effectiveness

Workstation payback: 3 years

SIR: 3.2

Common area payback: 0.5 years

SIR: 18.9

Installed cost: $22 each, without metering capacity

Tech life: 10 years

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2016

Chiller Plant Control Optimization System

Best suited for centrifugal chilled water plants with cooling loads > 3 million tons/year.

Description & Lessons Learned

- Optimizes chiller plant performance by monitoring and controlling five interdependent systems.
- Good option for retrofits because it increases chiller plant efficiency without requiring an expensive variable-speed drive on the chiller itself.
- Researchers also assessed all variable-speed loop (AVS) control (Hartmann loop) installed at the Eagleton Courthouse in St. Louis. Results were not released due to difficulties with the study design and the technology itself which is no longer being used at this location. This preliminary assessment also found that AVS technology costs did not justify installed costs.

Installation

- 3 to 4 months installation
- Initial commissioning, 2 weeks. Siemens monitors performance for the 1st year and makes adjustments.

O&M

- Improved part-load efficiency and Delta T.
- Better visibility & control for plant operations with submetering, trending data and information on average performance in kW/ton.
- Additional ways to improve plant performance include Cooling Tower Leaving Water Temperature (ECWT) setpoint reset, Chilled-Water Supply Temperature (ChWST) setpoint reset and improved optimal equipment runtime.

Deployment

- Retrofit, new construction
- Product tested: Siemens, Demand Flow

Testbed Energy Savings

35% cooling energy savings

+/- 10.8% uncertainty due to estimated baseline

Testbed Cost Effectiveness

Payback: 5 years

SIR: 1.8

Installed cost: $310,000

Tech life: 10 years

» ASSESSMENT ON GSA.GOV

Submeters & Analytics: Full-Panel

Suitable across portfolio. Best suited to facilities without GSALink or a BAS.

Description & Lessons Learned

- Integrates hardware with software to monitor up to 42 circuits in a panel for granular electric consumption. Voltage taps power the system.
- High accuracy CTs had <3% error compared to reference grade meter. Pilot projects recommended to determine best practices, including changes to GSA billing practices.
- High-accuracy CTs are necessary for tenant billing.
- Size CTs to estimated power levels, as opposed to rated breaker values.
- Tracing loads to individual circuits can be challenging due to inaccurate panel schedules, obscure naming conventions, or lack of circuit tracing.

Installation

- < 2 day installation for 5 electrical panels with 96 breakers.
- Installed in high- and low-voltage panels and with limited space in the electrical room, demonstrating applicability throughout GSA's inventory.
- Requires certified electrician.

O&M

- Submeter data utilized in a detailed energy audit identified 3 ECMs.
- Integration into Skyspark, the analytics software for GSALink, took approximately 12 hours for an engineer experienced with the RESTful API.
- For buildings with GSALink, enables monitoring of end uses not typically integrated into the BAS, such as lighting and plug loads.
- For GSA buildings without a BAS or GSALink, enables the identification of ECMs and FDD that would not otherwise have this capability.

Deployment

- Retrofit, new construction
- Product tested: Enertiv

Testbed Energy Savings

10% HVAC energy savings

Measured tenant data center use was double the billing estimate.

Testbed Cost Effectiveness

Payback is site specific

<1 year at the testbed with accurate overtime billing and 1 ECM

SIR: 5

Installed cost:

Meter: $500–$800

Revenue CT: $30–$70

Standard CT: $3–$5

Tech life: 10 years

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Submeters & Analytics: Single-Circuit Meter

Suitable across portfolio. Best suited to tenant billing.

Description & Lessons Learned

- One meter measures each single- or three-phase load.
- Accuracy supports tenant billing. <2% measurement error, except when chillers were online but idling.
- Captured load profile trends accurately, even for high variability loads.
- Line of sight is important between wireless meters and gateway.
- One gateway per electrical room is recommended.
- If using a single CT on three-phase equipment, the load should be well balanced.

Installation

- 1 day installation for 3 separate gateways that collected data from 18 individual CTs and 6 meters distributed in 2 panels and 2 HVAC equipment disconnects.
- Requires certified electrician because the panel is opened.
- Installing meters in separate enclosures saves time and panel space. Troubleshooting can then be done without needing an electrician to open the panel.
- To decrease measurement uncertainty, size CTs to estimated power levels.

O&M

- Submeter data identified 7 ECMs.
- Wireless CTs can monitor systems not typically monitored by a BAS and can be integrated into GSALink.

Deployment

- Retrofit, new construction
- Products tested: Meazon DinRail ULTRA 3-Ph and Centrica, Pan-42

Testbed Energy Savings

Savings not measured

Testbed Cost Effectiveness

Payback is site specific depending on ECMs implemented

Installed cost: $470 for equipment per measured load; $132/load for bulk purchase

$431/load for installation

$12 to $48 per meter per year for analytics package. No ongoing costs if pulling meter data into a separate analytics package

Tech life: 10 years

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2019

042

Submeters & Analytics: Wireless CTs

Suitable across portfolio. Best suited to FDD.

Description & Lessons Learned

- Clip on sensors powered by current in electrical wire; no meter, batteries or conduit.
- Accurately tracks load profile trends.
- Not accurate enough for tenant billing. 7% average error in measurement, up to 52% for VAV loads with heavy cycling.
- Because CTs are powered by electric current going through the wires they can record only currents above 0.75–1A (90–120W for 120V).
- When entering voltage and power factor assumptions, enter the best estimate possible, as this will impact data accuracy.

Installation

- 1 day installation for 144 individual CTs distributed across 13 panels and 4 HVAC equipment disconnects.
- Configuration software streamlined the process, providing real-time feedback and helping debug sensor problems.
- Requires certified electrician because the panel is opened.

O&M

- Submeter data identified 7 ECMs.
- Wireless CTs can monitor systems not typically monitored by a BAS and can be integrated into GSALink.

Deployment

- Retrofit, new construction
- Product tested: Centrica, Pan-10 and Pan-12

Testbed Energy Savings

1.3% total building electricity

Testbed Cost Effectiveness

Payback is site specific

<1 year based on 1 ECM at the testbed

SIR: 13

Installed cost: standard 3-phase circuit CT: $35–$50

No meter required

No ongoing subscription costs

Tech life: 10 years

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2015

Wireless Thermostats for Pneumatic Systems

Best suited for facilities with pneumatic control.

Description & Lessons Learned

- Provide conventional pneumatic systems with Direct Digital Control (DDC) functionality.
- Recommended for deployment in any facility with conventional pneumatic controls.
- Test wireless signals and consider the effects of thermal mass on potential energy savings.

Installation

- Pre-installation, test wireless signal transmission and train facility operators.
- In planning a WPT occupied/unoccupied control strategy, consider the effects of thermal mass on temperature changes.

O&M

- Requires no more maintenance than a conventional pneumatic control system.
- Helps with other maintenance issues, such as identifying air leaks, using built-in pressure sensors that report to the BAS.

Deployment

- Retrofit
- Product tested: Cypress Envirosystems, Wireless Pneumatic Thermostat

Testbed Energy Savings

43–52% heating energy savings; 20% cooling energy savings

(Assuming a basic occupied/ unoccupied control strategy and a 62-degree setpoint in Baltimore)

Testbed Cost Effectiveness

Payback: 5.3 years

SIR: 1.9

Installed cost: $0.70/ft²

Tech life: 10 years

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2021

HVAC

Condensing Boilers

Best suited for replacement of conventional boilers. Life-cycle cost effective when 3–5 % more efficient than high-efficiency boilers.

Fan Belts: Synchronous and Cogged

VAV Fans, retrofit with synchronous drive belts. CV Fans, replace at end-of-life with cogged V-belts.

Software-Controlled Switched Reluctance Motor

Best suited to retrofitting of constant-speed motors and end-of-life replacement for premium-efficiency motors.

Small Circulator Pumps with Automated Control

Best suited to end-of-life replacement for constant-speed pumps. Pumps used for DHW recirculation, small heating and chilled water systems, solar hot water and geothermal heat pump applications are all candidates for replacement.

Variable Refrigerant Flow

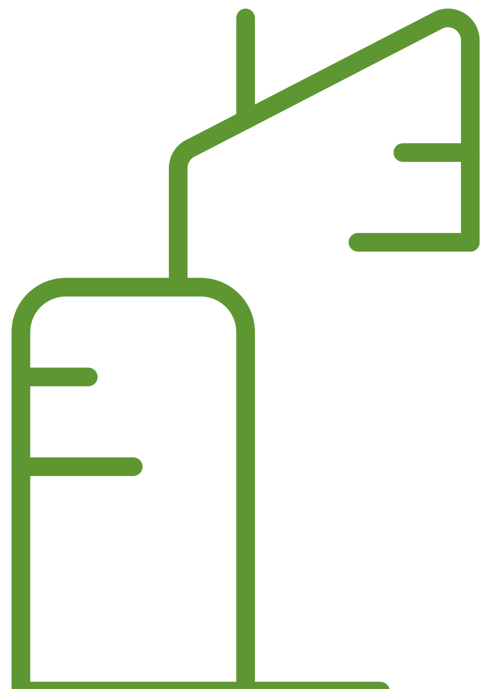
Best suited for buildings that are 5,000 to 100,000 ft^2 with electric reheat in cold climates, with limited room for ductwork changes.

Variable-Speed Direct-Drive Screw Chiller

Best suited for end-of-life replacement.

Variable-Speed Magnetic Bearing Chiller

Best suited for end-of-life replacement.



Condensing Boilers

Best suited for replacement of conventional boilers.

Description & Lessons Learned

- Captures heat that is lost through steam in conventional boilers.
- Life-cycle cost effective when 3–5 % more efficient than high-efficiency boilers.
- Favorable results depend on proper operation and application.

Installation

- Select a boiler that meets maximum thermal load without excess capacity; do not rely on previous plant sizing calculations.
- Select boilers with a low turndown ratio and low minimum flow requirement.

O&M

- To operate in condensing mode, a return water temperature (RWT) below 130°F is required.
- Given the same parameters, boilers in mild climates operate in condensing mode for a higher percentage of time than do boilers in more extreme climates.
- Condensing boilers typically require installation of condensate neutralizers, with annual recharging or replacement.

Deployment

- End-of-life
- Products tested: Harsco Patterson-Kelley: P-K MACH Condensing Boiler (Atlanta) Cleaver-Brooks: ClearFire-C (Denver)

Testbed Energy Savings

14%–41% natural gas heating energy savings

Testbed Cost Effectiveness

Incremental payback: 4–7 years

SIR: 5.9

Average incremental installed cost: $4.1 MBtu/h

Condensing—$42.60/MBtu/h

High-efficiency—$38.50 MBtu/h

Tech life: 25 years

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Fan Belts: Synchronous and Cogged

012

VAV Fans, retrofit with synchronous drive belts. CV Fans, replace at end-of-life with cogged v-belts.

Description & Lessons Learned

- Reduces friction and bending resistance by notching the inner side of the belt, allowing for more efficient fan performance. Synchronous belts also reduce slippage by integrating teeth with slots on the motor pulley.
- Synchronous drive belts and cogged v-belts both reduce energy consumption.
- Correct fan choice and expert installation are key.

Installation

- To maintain optimal fan speeds, it is critical that belts are properly sized.
- Synchronous drive belts not recommended for CV fans.

O&M

- 75% lower O&M for synchronous. Cogged O&M equivalent to standard v-belts.

Deployment

- Retrofit, end-of-life
- Products tested: Synchronous—Gates® Poly Chain® GT® Carbon™; Cogged—Super HC® Molded Notch Belts

Testbed Energy Savings

2–20% fan energy savings for synchronous drive belt on VAV fan

1–9% fan energy savings for cogged belts on CV fans

Testbed Cost Effectiveness

Synchronous
Initial installation payback: < 4 years

SIR: 0.8

Repeat installation: immediate payback

$1,280 initial cost/$901 incremental

$372 replacement/$-7 incremental

Cogged
Payback: < 1 year

SIR: 6.2

$419 initial cost/$40 incremental

Tech life: 3 years

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2019

Software-Controlled Switched Reluctance Motor

Best suited to retrofitting of constant-speed motors and end-of-life replacement for premium-efficiency motors.

Description & Lessons Learned

- High-rotor-pole switched reluctance motor with a programmable variable-speed drive and software that provides real-time cloud-based monitoring and control (not yet IT-Security cleared.)
- Does not rely on rare earth materials.
- Smart motor was more efficient under all circumstances and cost about 1/2 as much as a premium motor and VFD.
- Early production system was noisy 94 dBA, manufacturer reports that new design has dropped to 84 dBA; new motor feet will reduce noise by an additional 7-12 dBA.

Installation

- Drop-in replacement. 12 hours for pump motor, 2–4 hours for fan motor.

O&M

- Reduced maintenance—bearings of the smart motor are permanently sealed, so no regular lubrication or maintenance is required.
- Unlike some VFD motors, the smart motor does not have an LCD to display parameters, such as energy use and rotational speed. Facility staff deemed this a limitation, though parameters can be viewed and set by directly connecting the smart motor to a computer or via cloud-based monitoring.
- Remote real-time monitoring and control not tested in GSA evaluation due to timeline for IT-Security clearance. GSA staff thought this capability would be helpful. Remote monitoring was tested in a concurrent NREL evaluation where the motor remotely turned off after a piece of foam lodged in the fan preventing possible motor damage.

Deployment

- End-of-life, new construction, retrofit
- Product tested: Smart Motor Company (now Turntide) 10 hp motor; Concurrent NREL assessment tested a 1.5 hp motor

Testbed Energy Savings

4% compared to premium-efficiency motor + VFD

71% savings compared to a constant-speed motor *(concurrent NREL assessment of a 1.5 hp motor)*

33% compared to a standard efficiency motor + VFD *(concurrent NREL assessment of a 1.5 hp motor)*

Testbed Cost Effectiveness

Retrofit payback compared to constant-speed motor: 1 - 3 years

End of life payback compared to premium motor + VFD: Immediate; *smart motor is ~1/2 as expensive as premium motor + VFD*

Tech life: 12 years

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Small Circulator Pumps with Automated Control

Best suited to end-of-life replacement for constant-speed pumps. Pumps used for DHW recirculation, small heating and chilled water systems, solar hot water and geothermal heat pump applications are all candidates for replacement.

Description & Lessons Learned

- Pumps < 2.5 HP with variable-speed electronically commutated motors (ECM) and onboard control algorithms.
- Pumps were life-cycle-cost effective for DHW applications and for the AHU application running 20/hrs/day. They should be considered for all end-of-life replacements.
- Pumps serving multiple coils will have greater savings.
- Convert three-way bypass valves to two-way valves.
- Use the pump's pre-programmed internal control modes and rely on the BAS for simple on/off control.

Installation

- 2 hours more installation time than a standard pump in order to program the automated control.
- Pumps that were larger than necessary for the required flow saved energy, but had higher installed costs and lower wire-to-water efficiencies than right-sized pumps.

O&M

- Less maintenance—no need to grease bearings or replace pump seals.
- More operational visibility.
- Pre-programmed control sequences reduced expense of setting up points in the BAS.

Deployment

- End-of-life, new construction
- Product tested: Grundfos, Magna3

Testbed Energy Savings

26% to 96%

Incremental annual savings DHW: 587–1,039 kWh/year

Incremental annual savings AHU: 688 kWh/year

Testbed Cost Effectiveness

Payback compared to market standard: 3.6

SIR: 4.2

Incremental costs DHW: $575

Incremental costs AHU: $500

Tech life: 15 years

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2012

Variable Refrigerant Flow

Best suited for buildings that are 5,000 to 100,000 ft² with electric reheat in cold climates, with limited room for ductwork changes.

Description & Lessons Learned

- Uses refrigerant as cooling/heating medium and offers independent temperature control to rooms.
- Primary HVAC system in Europe, Japan & China, 3% U.S. installed base.
- Pilot project. Buildings targeted for VRF should meet specific criteria. VRF implementation in GSA portfolio must overcome obstacles.

Installation

- Thin profile is advantageous in historic buildings with limited room for ductwork.
- Fan coil units can be sized to serve small spaces with independent temperature control, such as individual private offices.
- Commissioning of zone temperature control recommended.

O&M

- VRF systems are a mature technology ("9" on the TRF scale), with maintenance requirements similar to those of other distributed systems.
- Incremental maintenance: $0.023/ft²

Deployment

- New construction
- Product tested: Mitsubishi

Testbed Energy Savings

34% HVAC savings projected relative to code-compliant HVAC

Incremental Energy Savings over code-compliant HVAC: $0.29/ft²

Testbed Cost Effectiveness

Incremental payback: 11 years

SIR: 1.3

Incremental cost: $3/ft²

Cost-effective when premium is < $4/ft² compared to code-compliant HVAC

Tech life: 15 years

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Variable-Speed Direct-Drive Screw Chiller

Best suited for end-of-life replacement.

Description & Lessons Learned

- Variable-speed direct-drive (VSS) chiller with 3 rotors and a variable-speed motor. Capacity is controlled by regulating motor speed alone, no unloaders.
- VSS can match the performance of the Maglev chiller and should be considered alongside the Maglev as a viable replacement for chillers at end-of-life. At the Yates building, it was 11% more efficient and 36% less expensive.
- Employ a mechanical engineer to do a thorough economic and technical analysis for all facets of the chiller plant design. Consider #028, Control Optimization System for Chiller Plants, in the analysis.

Installation

- Quiet performance allows chillers to be placed closer to occupant spaces.
- When replacing an old chiller, perform a new heat gain/loss calculation to correctly size the new chiller.
- Look at your load profile, if the building spends most of the time at partial loads, prioritize energy consumption rate (kw/ton) at part load. If a facility operates 24/7/365 with a fairly high and constant internal load, such as at a data center, focus on a chiller's efficiency at maximum capacity.
- The variable-speed screw compressor is a universal design; the same compressor can be used in Phoenix, AZ or Fargo, ND.

O&M

- At the Yates building, the VSS runs more in shoulder season and was better able to handle swings in condenser water temperature than the Maglev chiller and could offer greater versatility to operate in unusual conditions not normally found in the climate zone in which it is installed.
- Reduced maintenance and fewer components to fail.
- Oil change is only required every 10 years. Annually take oil sample, send for analysis. Inspect and clean tubes, tighten connections.
- Noise levels are comparable between Maglev and VSS chillers.

Occupant Satisfaction

- No complaints were received from occupants or from operations personnel.

Deployment

- End-of-life, new construction.
- Individual site characteristics will determine the most cost-effective chiller technology for a particular application.
- Product tested: Carrier, AquaEdge Chiller.

Testbed Energy Savings

11% compared to Maglev chiller; +24 to -4% savings possible due to field measurement uncertainty

35% savings compared to code-compliant, as cooling loads decrease, efficiency increases

Testbed Cost Effectiveness

Payback compared to code-compliant: 5 years

SIR: 4.5

Chiller costs: 275-ton chiller

VSS—$119,000, $432/ton

Maglev—$185,000, $672/ton

Code-compliant, ~$333/ton

Tech life: 25 years

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2013

Variable-Speed Magnetic Bearing Chiller

009

Best suited for end-of-life replacement.

Description & Lessons Learned

- The variable-speed magnetic bearing (Maglev) chiller uses magnetic levitation to eliminate heat, noise and vibration associated with standard chillers, and improves efficiency when operating under small and partial loads.
- 35% more efficient than FEMP designated high-efficiency rotary screw chillers, as cooling loads decrease, efficiency increases.

Installation

- Quiet performance allows chillers to be placed closer to occupant spaces.
- When replacing an old chiller, perform a new heat gain/loss calculation to correctly size the new chiller.
- Look at your load profile, if the building spends most of the time at partial loads, prioritize energy consumption rate (kw/ton) at part load. If a facility operates 24/7/365 with a fairly high and constant internal load, such as at a data center, focus on a chiller's efficiency at maximum capacity. Build parts and labor warranty into scope – R7 requires 5 years.
- Power surges can cause control boards to short. Provide time/effort to study grid fluctuations. If there is a history of phase imbalance, look at power rectification. R7 requires surge protection in SOW.
- Consider condenser water supply temperature during design as well as consumption vs. demand charges. For effective performance of maglev chillers, water temperature must be considered during design.

O&M

- The elimination of friction removes the need for lubricating oil and the ancillary components required to support the oil system.
- Some of the pitfalls of the maglev include knowing when to stage on/off additional chillers and knowing how low to control the cooling tower water temperatures. Traditional control sequences may be counter-productive.
- Maglev chillers are modular so you can do piecemeal fixes which are easier.
- Multiple compressors and variable-speed direct-drive enable responsiveness to demand and curtailment requests from utilities.
- Maglev chillers have proprietary components, in particular the Turbocor Compressor from Danfoss, which can require multiple O&M vendors.
- Maglev turns at 10-times the speed of a VSS so components like capacitors need to be replaced. 7-10-year capacitor replacement & chiller overhaul runs $45K-$75K

Deployment

- End-of-life
- Individual site characteristics will determine the most cost-effective chiller technology for a particular application.
- Product tested: Danfoss, Turbocor

Testbed Energy Savings

42% cooling energy savings at testbed

-11% compared to VSS chiller; -24 to +4% energy use possible due to field measurement uncertainty

35% savings compared to code-compliant, as cooling loads decrease, efficiency increases

Testbed Cost Effectiveness

Incremental payback: 8 years

Incremental SIR: 2.9

Incremental cost: $400/ton (150-ton chiller)

Tech life: 25 years

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2021

Lighting

Advanced Lighting Controls and LED

Facilities with high utility rates, utility rebates, open-office plans

TLED Lighting Retrofits with Dedicated Drivers

Fixtures where lenses and sockets are in good condition and ALC is useful.

LED Downlight Replacement Lamps for CFL Fixtures

Where advanced lighting controls are not desired or useful.

LED Fixtures with Integrated Advanced Lighting Controls

Consider for retrofits with EUI > 3.25 kWh/ft²/year and utility rates > $0.10 kWh.

Wireless Advanced Lighting Controls

Integrate with LED fixtures. Consider for retrofits with EUI > 3.25 kWh/ft²/year and utility rates > $0.10 kWh.

M&V results demonstrate broad deployment potential for GSA

Advanced Lighting Controls and LED

Best suited for facilities with high utility rates, utility rebates, open-office plans.

Description & Lessons Learned

- 5 different combinations of LED + controls—tuning and occupancy sensing.
- The more efficient the lighting, the more challenging it is for ALC to achieve positive ROI.
- Light-level tuning can be critical for occupant satisfaction. Tuning is a standard capability of ALC and is available as a fixture adjustment option in systems without advanced controls.

Installation

- More time was needed (10 to 15 minutes per fixture) to install the separate add-on controls.

O&M

- Staff liked the ability to drill down to individual fixtures with Flow Lighting, Enlighted and Lutron but this added to control costs.
- Philips Spacewise was easier to commission but learning curve for remote-programming was steep.

Occupant Satisfaction

- After installation of the new lighting systems and before commissioning was completed, some occupants found the light too bright and fabricated barricades to block it. Once the light levels were reduced, occupants were more comfortable and removed their barricades.

Deployment

- Retrofit or new-construction.
- Products tested: Enlighted, Philips Spacewise, Flow Lighting, Patriot and RAB LED with Lutron.

Testbed Energy Savings

43% control savings from LED baseline—21.5% tuning, 21.5% occupancy, limited daylight availability at testbed

Incremental savings for controls: 0.82 kWh or $0.09

Testbed Cost Effectiveness

Payback: 7.1

SIR: 2.8

Incremental cost for controls: $65 or $0.65/ft^2 assuming 1 fixture per 100 ft^2

Tech life: 20 years

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2016

TLED Lighting Retrofits with Dedicated Drivers

030

Best suited for fixtures where lenses and sockets are in good condition and ALC is useful.

Description & Lessons Learned

- LED Lamps that use the existing lens and fixture and include dedicated LED drivers. (TLED, Type-C)
- Rated light levels can differ from measured light levels. NEXT lamp had similar luminance rating to Cree but higher light output at test-bed sites.
- To assess fit, light levels and glare, test a small number of lights before committing to purchase.

Installation

- No special tools or electrical modifications were necessary during installation.
- NEXT compatible with shunted and unshunted lampholders.
- Cree compatible with unshunted only. Cree wire harnesses allow lights to be moved in the fixture but won't always fit legacy situations and won't work with master/remote configurations. Cree installation may be slightly more time consuming than LFL replacement.

O&M

- No annual maintenance required.
- Projected 67% increase in technology life leading to $110 in maintenance savings over the lifetime of the lamp.

Occupant Satisfaction

- Generally satisfied, though there were issues with Cree not providing enough light in a 3–2 conversion in an interior workspace in Dallas.

Deployment

- Retrofit or re-lamping existing fluorescent fixtures.
- Products tested: NEXT, 4-foot Linear LED
Cree, UR Series Upgrade Kit

Testbed Energy Savings

27%–29% lighting energy savings

$6.80/year–$7.22/year
energy cost savings

Testbed Cost Effectiveness

Payback: 6 years @ $50 fixture cost and avg. installation cost

SIR: 2

Installed cost:
Equipment: $40–$70
Labor: $34–$68

Tech life: 12 years

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LED Downlight Replacement Lamps for CFL Fixtures

Best suited where advanced lighting controls are not desired or useful.

Description & Lessons Learned

- LED replacement lamp that uses the same four-pin socket and electronic ballast as an incumbent CFL.
- LED downlight replacement lamps produce satisfactory light levels and light distribution with reduced maintenance.
- Glare can be an issue if a replacement kit sits too low in the recessed fixture of the existing downlight housing. Check with a manufacturer and/or conduct trial installation.

Installation

- LED downlight replacement lamps use the same four-pin socket and electronic ballast as an incumbent CFL.

O&M

- LED downlight lamps last four to six times as long as CFL. Maintenance reduced by 20%.

Occupant Satisfaction

- Occupants generally satisfied with light quality.

Deployment

- Retrofit
- Product tested: Lunera, Helen Lamp

Testbed Energy Savings

40–50% lighting energy savings over typical CFL lamps

Savings $6.37 per lamp @ $0.11/kWh

Testbed Cost Effectiveness

Payback: <3 years

SIR: 4.2

Lamp cost: $22

Tech life: 13 years

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2015

LED Fixtures with Integrated Advanced Lighting Controls

024

Best suited consider for retrofits with EUI > 3.25 kWh/ft²/year and utility rates > $0.10 kWh.

Description & Lessons Learned

- LED fixtures with onboard sensors dynamically manage lighting using occupancy sensing and daylight harvesting; integrated controls reduce complexity of installation and setup.
- Integrated systems recommended for renovations and end-of-life replacement; retrofits for spaces with high baseline lighting use.
- Turnkey aspect of integrated sensors and controls is advantageous over stand-alone ALC systems.

Installation

- Compared to LEDs with separate control systems, LEDs with integrated ALCs require minimal setup. Turnkey fixture and controls package, simple implementation and commissioning.
- Handheld remote controls easily program and assign zones to individual fixtures.

O&M

- Longer LED lamp lifetimes reduces maintenance; LED lamp life (50,000 hours) is twice that of CFL (25,000 hrs).

Occupant Satisfaction

- Occupants largely satisfied with the retrofit lighting and controls system, with some interest in more individual control.

Deployment

- Retrofit, new construction
- Product tested: Philips Lighting, SpaceWise

Testbed Energy Savings

69% lighting energy savings when compared to GSA average of 3.25 kWh/ft²/year

Testbed Cost Effectiveness

Incremental payback*: 1 year

SIR*: 12.7

Retrofit payback*: 5 years

SIR*:3.2

**including estimated maintenance savings*

Installed cost: $3.29/ft² for retrofit, and $0.82 for new construction or major renovation

Tech life: 15 years

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2015

Wireless Advanced Lighting Controls

Best suited for integrating with LED fixtures. Consider for retrofits with EUI > 3.25 kWh/ft²/year and utility rates > $0.10 kWh.

Description & Lessons Learned

- Enables advanced lighting control (ALC) functionality without the expense of installing dedicated control wiring.
- Energy savings are significant but heavily dependent on baseline conditions.

Installation

- Wireless networking enables ALC functionality without the expense of installing dedicated control wiring. Clear communication of design intent and commissioning process is essential for successful installation.

O&M

- Advanced wireless controls allow building management greater flexibility in varying light levels according to user preferences.

Occupant Satisfaction

- User education on design intent and implementation is key, along with prompt response to occupant feedback by continued system design and commissioning improvements.

Deployment

- Retrofit, new construction
- Product tested: Daintree, ControlScope
- Tested product is an older model that has been updated since GPG evaluation.

Testbed Energy Savings

54% lighting energy savings with ALC based on GSA average EUI of 3.25 kWh/ft²

78% lighting energy savings including LED wattage savings

Testbed Cost Effectiveness

Incremental payback: 5 years

SIR: 2.9

Retrofit cost: incremental cost of wireless ALC ~ $1/ft²

Tech life: 15 years

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2021

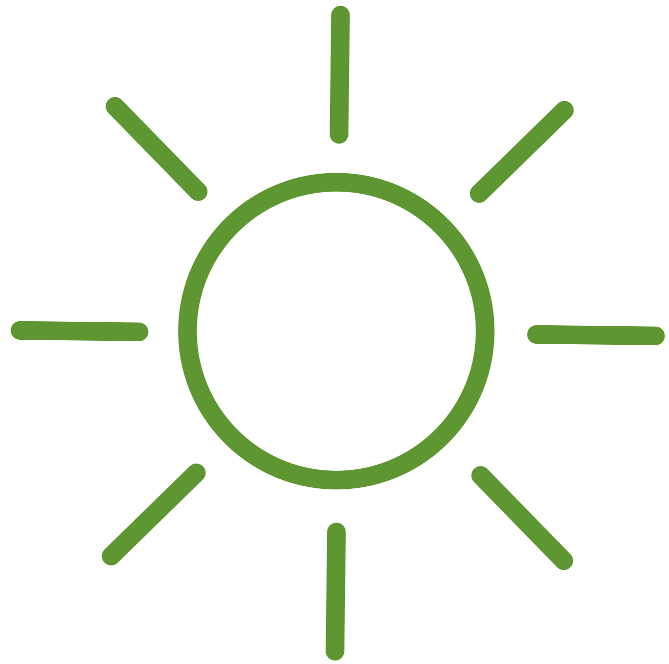
Renewables

Photovoltaics

PV effective even in 4-season climates.
Price should drive PV selection.

PV Resilience: Addressing Weather Vulnerabilities in Existing Systems

Small up-front investments in locking hardware, clamps and through-bolting can help protect PV arrays.



2012

Photovoltaics

PV effective even in 4-season climates. Price should drive PV selection.

Description & Lessons Learned

- Commercial-scale high-efficiency crystalline PV delivers practical energy solution.
- 5 PV systems tested in Midwestern climate and found effective even in diffuse, 4-season climates.
- Price should drive PV selection.
- System modeling is a highly accurate performance guide
- Thin-film outperforms crystalline PV with a unique form factor.

Installation

- Stabilizing installation ballast is needed depending on the design wind speed and tilt angle of the array; higher array tilt catches more wind and requires more ballast.
- Additional installation guidance can be found here: http://www.nabcep.org/wp-content/uploads/2012/08/NABCEP-PV-Installer-Resource-Guide-August-2012-v.5.3.pdf.

O&M

- Modeling tools produce accurate simulations for both sunny and cloudy climates.

Deployment

- Renewable.
- Product tested: Sunpower, Evergreen Solar, Solyndra, United Solar Ovonic, Abound Solar.

Testbed Energy Savings

2MW produced 2,384,137 kWh,
Savings = $0.22/kWh

Testbed Cost Effectiveness

Payback: 8 years @ 2015 pricing
(17 years @ 2011 pricing)

SIR: 3

Cost: $2.16/W avg. commercial cost 2015 (http://www.nrel.gov/docs/fy15osti/64746.pdf)

Tech life: 25 years

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PV Resilience: Addressing Weather Vulnerabilities in Existing Systems

Small up-front investments can help protect PV arrays.

Description & Lessons Learned

- To better understand why some PV systems failed after the 2017 hurricane season while others survived, GPG hired DOE national laboratories to conduct post-storm field inspections and create guidance to help agency managers identify the most common PV vulnerabilities during weather events.
- Many corrective actions are low cost.
- Consult qualitifed engineers to integrate best practices
- In every region of the United States, PV failures occur in response to routine as well as severe weather events.

Post-Storm Field Inspections

- Inadequate fasteners were found across all sites. Small up-front investments in locking hardware, clamps and through-bolting can help protect PV arrays.
- Structural vulnerabilities exhibit the greatest safety, performance and financial risks. Wind is the most damaging weather factor and also the most complex to understand and plan for.
- Building a system that is more likely to survive a severe storm can increase construction costs, but these costs can be recovered during the life of the system, through reduced maintenance and lifecycle costs.
- Instead of addressing isolated failure points, systems should be designed from the ground up to resist severe storms and to address location-specific conditions, such as wind speeds, loads, and topography.
- Current codes and standards are inadequate to address weather-related vulnerabilities, so it is critical to hire a consulting engineer to assist with identifying and correcting them.catches more wind and requires more ballast.

Key Vulnerabilties and Corrective Actions

- Top down clamps loosening or bending. To correct: Use throughbolting or top-down clamps with improved features.
- Inadequate structural attachments to building in roof arrays. To correct: Add mechanical attachments to improve structural integrity.
- Improper wire management. To correct: Protect wires from weather and support every 12 inches with clamps, clips or ties.
- Inadequate electrical enclosures. To correct: Use proper NEMA-rated enclosures based on the site's environmental conditions.
- Unobstructed wind forces. To correct: Use a wind calming fence to reduce wind forces on the PV system.
- Loose debris and equipment. To correct: Secure or remove loose equipment and debris from the area around the PV system.

Estimated Retrofit Costs

Proper Torquing 0.05–2.5 ¢/W
Use calibrated torque drivers & audit the results

Locking Fasteners 0.1–1.4 ¢/W
Most common point of failure

Through Bolting 0.6 ¢/W
More secure than top-down clamps

Wind-Calming Fence 6–14 ¢/W
Wind on perimeter rows can propagate inward

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Water

AWT: Advanced Oxidation Process for Cooling Towers

Consider proven alternative water treatments for all cooling towers.

AWT: Electrochemical Treatment for Cooling Towers

Consider proven alternative water treatments for all cooling towers.

AWT: Monitoring & Partial Water Softening

Consider proven alternative water treatments for all cooling towers.

AWT: Salt-Based & Chemical Inhibition

Consider proven alternative water treatments for all cooling towers.

Catalyst-Based Scale Prevention for DHW

Facilities with hard water > 121 MG/L.

Weather Station for Irrigation Control

Areas with intermittent rain. Turnkey water-based irrigation systems recommended.

M&V results demonstrate broad deployment potential for GSA

2018

AWT: Advanced Oxidation Process for Cooling Towers

039

Suitable for all cooling towers.

Description & Lessons Learned

- Photochemical treatment oxidizes minerals & contaminants
- Met all success criteria for water savings, reduction in chemical costs, water chemistry and cost-effectiveness
- In addition to scale, biofilms have a significant impact on heat-transfer efficiency. Biofilms were eliminated with AOP system.

Installation

- Installation of the relatively small device (20"h x 15"w x 6"d) took only a few hours, including the simple tie-in process, which consists of connecting the injector hose to the cooling tower basin.

O&M

- Annual savings of $2,522 per year, due to reduced chemical expense and a 50% reduction in annual O&M hours.
- A borescope view of the two chiller tube condenser bundles, captured after the system had been running for more than two years, revealed a significant decrease in condenser tube fouling, though energy savings were not assessed.
- Each unit draws 396 watts per 24/7 which increased site energy use by $1,137.

Deployment

- Retrofit
- Product tested: Advanced Oxidation Process (AOP) system by Silver Bullet

Testbed Water Savings

23–30% water savings

Blowdown was not measured

Testbed Cost Effectiveness

Payback: 2 years

SIR: 7

Normalized cost: equipment: $22,040 (Two 250-ton cooling towers)

Installation: $1,485

Installed cost per ton: $44

Leasing + service cost is comparable to traditional chemical treatment

Tech life: 15 years

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2018

AWT: Electrochemical Treatment for Cooling Towers

038

Suitable for all cooling towers.

Description & Lessons Learned

- Electrochemical process sequesters scale in reactor tubes and creates chlorine a natural biocide.
- Effective at controlling scale, corrosion and biological growth without added chemicals.
- Training local O&M staff is critical.

Installation

- Small footprint and a simple tie-in process.
- One potential challenge is getting the equipment to the roof.
- At the test-bed location, the system had four 5-foot tall reactors mounted on a 4ft-by-1ft skid and weighed just under 500 lbs. The size of the equipment and the number of reactors will vary based on cooling tower size and water condition.

O&M

- Eliminating added chemicals saved $4,080 per year. The technology generates chlorine reducing the need for cooling tower cleanings from four per year to two per year, with estimated annual savings of $1,200. Savings were offset by an annual vendor maintenance contract of $6,000.

Deployment

- Retrofit
- Product tested: UET by Dynamic Water Technology

Testbed Water Savings

32% water savings

99.8% reduction in blowdown

Testbed Cost Effectiveness

Payback: 2.5 years

SIR: 6

Installed cost: $15,000

Installed cost per ton: $151

Tech life: 15 years

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2020 045

AWT: Monitoring & Partial Water Softening

Suitable for all cooling towers.

Description & Lessons Learned

- Continuous monitoring determines the optimal amount of blowdown to satisfy water chemistry targets. Sidestream filtration removes suspended matter while dispensing softened water.
- Reduced blowdown and saved water, works alongside traditional chemical treatment.
- Training local O&M staff is critical.

Installation

- Installing the skid, wiring and plumbing was straightforward
- The installation took two days, though existing piping made it easier.
- If the skid can be situated close to the cooling water supply and return piping, the slipstream piping runs are short.

O&M

- Works alongside traditional chemical treatment and does |not significantly change plant.
- Maintenance consisted of monitoring the system to make sure it was operational and replenishing salt.

Deployment

- Retrofit
- Product tested: Continuous Monitoring and Partial Softening by Aqualogix

Testbed Water Savings

15% water savings

52% reduction in blowdown

Testbed Cost Effectiveness

Payback: 3 years

SIR: 6

Testbed cost: equipment: $31,100 (two 350 ton cooling towers and 1,450 ton cooling tower)

Installation: $38,371

Installed cost per ton: $33

Tech life: 15 years

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AWT: Salt-Based & Chemical Inhibition

Suitable for all cooling towers.

Description & Lessons Learned

- Salt-based system removes hardness without added chemicals, chemical scale inhibition uses proprietary chemicals.
- Both systems reduced blowdown and saved water.
- Training local O&M staff is critical.

Installation

- Salt-based system required ~ 8 ft² of floor space for two brine tanks.
- Chemical scale inhibition system required 8 ft² of floor space for three 5-gallon containers and a double-walled mixing basin and sand filter.
- Chemical system also required additional plumbing with dedicated supply and return lines.

O&M

- Salt-based system reduced annual maintenance 47% from 152 hours to 80 hours. It also reduced ongoing material costs by $2,768 a year, by eliminating almost all chemical use and using a less expensive salt regeneration process.
- The chemical scale inhibition system reduced annual maintenance 48% from 132 to 69 hours but increased the ongoing maintenance contract by $5,100 a year from $8,400 to $13,500, due to a higher quality of chemicals.

Deployment

- Retrofit
- Products tested: Salt-based system by Water Conservation Technology International; Chemical scale inhibition by Terlyn Industries

Testbed Water Savings

23% water savings

94%–99% reduction in blowdown

Testbed Cost Effectiveness

Payback: 2–3 years

SIR: 5–7

Salt-Based Cost:
Equipment: $18,100 (three 500-ton cooling towers)

Installation: $11,500

Installed cost per ton: $20

Chemical scale cost:
Equipment: $17,103 (two 600-ton cooling towers)

Installation: $15,408

Installed cost per ton: $27

Tech life:15 years

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Catalyst-Based Scale Prevention for DHW

Best suited for facilities with hard water > 121 MG/L.

Description & Lessons Learned

- Pipe with helical insert prevents calcite buildup potentially saving energy.
- Device sizing is key to effective performance. Appropriate element capacity yields maximum effectiveness.

Installation

- Technology is installed by removing a section of the cold-water and recirculating line and replacing it with the pipe containing the helical insert.
- Unit sizing corresponds to pipe diameter and is determined by the flow rate of water to be treated.

O&M

- Little training is needed for site personnel, as there are no moving parts or chemicals added.
- In installations where there is high iron content, the catalytic device may require periodic cleaning.
- In systems without a drain, calcite can form a soft sediment in the bottom of the tank, which should be removed either manually or with a wet/dry vacuum every 18 to 24 months.

Deployment

- Retrofit, new construction
- Product tested: NaturalSof, formerly Fluid Dynamics, Scaletron

Testbed Savings

Not measured

Testbed Cost Effectiveness

Payback: immediate

SIR: 15.5

Installed cost: $1,692

Tech life: 15 years

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2015

Weather Station for Irrigation Control

Best suited for areas with intermittent rain. Turnkey weather-based irrigation systems recommended.

Description & Lessons Learned

- Uses live local weather data to calculate irrigation needs, either as a turnkey system or connected to a building automation system (BAS).
- Off-the-shelf turnkey weather-based systems are recommended for broad deployment.
- BAS-integrated solutions may enable efficiencies but will need more support.

Installation

- BAS-Connected challenging to program and not fully realized.
- Until clearer guidelines for BAS integration can be established, turnkey weather-based systems are recommended.

O&M

- BAS-connected or other integrated systems require staff training on equipment, systems monitoring, control, and adjustment.

Deployment

- Retrofit
- Product tested: Campbell Scientific (Custom)

Testbed Energy Savings

20–40% site irrigation water savings projected

66% site irrigation water savings estimated at test-bed

Testbed Cost Effectiveness

Payback: 1–2 years @ GSA avg. water rate of $11.87/kgal

SIR: 6.5–13.7 years @ GSA avg. water rate of $11.87/kgal

Test-bed Installed cost: $21,000

$700/year maintenance

Smart irrigation systems are cost effective at water rate of $1.40/kgal with water use of 4 Mgal/year

Tech life: 15 years

ASSESSMENT ON GSA.GOV

2021

Limited GSA Potential

Building Envelope: Dual Zone Shades

Best suited to facilities where outside views are critical.

Energy Management: Socially Driven HVAC for Personal Control

Facilities where thermal comfort is an issue. Savings greatest in intermittently occupied facilities with high energy costs and narrow deadbands.

Energy Management: Wireless Sensor Networks for Data Centers

Best suited to data centers.

HVAC: High-Performing Commercial Rooftop Units

Best suited for end-of-life replacement of standard RTUs. Savings greatest in hot, humid climates.

Renewables: Honeycomb Solar Thermal Collector

Best suited for central hot water systems with electric heating and large uniform loads.

Renewables: Wood-Pellet Biomass Boiler

Facilities in cold climates that use fuel oil and are located within 50 miles of a biomass pellet mill.

M&V results demonstrate limited deployment potential for GSA

2018

Dual-Zone Shades

Best suited to facilities where outside views are critical.

Description & Lessons Learned

- Upper louvered blind maximizes daylight. Lower roller shade controls glare and reduces heat transfer, while preserving views.
- Not broadly recommended to replace venetian blinds from a cost-savings standpoint. GSA's legacy venetian blinds are more energy efficient than more contemporary roller shades.
- Manual upper shades provided the best balance between financial performance and occupant response.

Installation

- Installation and commissioning of the DZSC shades was fairly straightforward with some minor problems due to inadequate installation instructions and improper wiring.

O&M

- No impact to O&M.

Occupant Satisfaction

- 80% survey respondents preferred dual-zone shades over existing vertical blinds.
- Visual discomfort due to glare was reduced compared to the original vertical blinds.

Deployment

- New construction or replacement of rollershades at end-of-life.
- Product tested: LouverShade, Dual Zone Louvershade

Testbed Energy Savings

150% to 300% increase in lighting energy and 5% to 36% increase in cooling compared to venetian blinds

25% to 51% decrease in lighting energy and 4% increase to 15% decrease for cooling compared to fabric roller shades

Incremental savings for manual dual-zone compared to roller shades: 0.60 kWh/ft^2/year

Testbed Cost Effectiveness

No payback compared to venetian blinds

End-of-life payback compared to rollershade: 16 years

SIR: 1

Installed cost: \$12/ft^2

Tech life: 15 years

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2015

Socially Driven HVAC for Personal Control

Best suited for facilities where thermal comfort is an issue. Savings greatest in intermittently occupied facilities with high energy costs and narrow deadbands.

Description & Lessons Learned

- Uses direct input from occupants in temperature management. Tracks user preferences over time. Optimizes energy savings by widening the deadband when there is no occupant input.
- Saved energy, increased occupant satisfaction and reduced calls to maintenance. Energy savings alone may not cover subscription costs.
- Improved understanding of the economic value of non-energy benefits may accelerate technology's adoption, e.g., value placed on personal control over workplace temperature.

Installation

- Meeting IT security requirements was challenging and moving from a pilot project to full deployment would require additional IT assessment.
- SaaS solution includes user interface software to heat/cool individually-zoned work environments, and a controls package which communicates with the BMS.
- NOTE: This technology has not been IT screened and currently can not be used by GSA facilities.

O&M

- Maintenance calls requesting temperature changes were reduced by 59% over the three-month test period. Though the technology had a significant reduction in hot/cold calls it's not clear that this will result in savings because of the way GSA funds maintenance contracts.

Occupant Satisfaction

- 83% of occupants were more satisfied with their thermal conditions.

Deployment

- Retrofit, new construction
- Product tested: Building Robotics, Comfy (now owned by Siemens)

Testbed Energy Savings

20% cooling energy savings

47% heating energy savings

Testbed Cost Effectiveness

SIR: NA

Installed cost: \$0.12–\$0.60 ft²
(subscription)

Tech life: NA

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2012

Wireless Sensor Networks for Data Centers

Best suited for data centers.

Description & Lessons Learned

- Dense network of wireless sensors provides real-time information that enables facility operators to better manage HVAC cooling loads in data centers.
- Simplified assessment tools limit power interruption.

Installation

- Permanent installation requires multiple interruptions of facility power.
- An assessment kit developed by LBNL during the study provides many of the full network's benefits while reducing deployment time and power interruptions.

O&M

- Full deployment of a permanently installed wireless sensor network provides valuable real-time information for on-going data center performance optimization.

Occupant Satisfaction

- Helps identify energy saving opportunities and assess the impact of recommended measures.

Deployment

- Retrofits, new construction
- Product tested: Synapsense, Wireless Monitoring and Cooling Control Solution

Testbed Energy Savings

17% total data center energy savings

48% cooling load reduction

Testbed Cost Effectiveness

Payback: 1.4 years

SIR: 7.2

Installed cost: $7.74/ft^2$

Tech life: 10 years

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High-Performing Commercial Rooftop Units

034

Best suited for end-of-life replacement of standard RTUs. Savings greatest in hot, humid climates.

Description & Lessons Learned

- RTU with one variable-speed inverter driven compressor, composite condenser fans with variable-speed electronically commutated motors, and controls that can be integrated with optional BACnet or LonMark building automation systems (BASs).
- Advanced RTUs exceeded baseline code-compliant efficiency between 26–40%, particularly at higher outdoor air temperatures. They should be considered for all end-of-life replacements.
- For RTUs that have not yet reached end of life, advanced rooftop control (ARC) retrofits should be considered. A PNNL field study of 66 RTUs retrofitted with advanced controls found energy savings ranging from 22% to 90%, with an average 57% savings and 3 year payback (@ $0.10/kWh).

Installation

- Advanced RTU may have a different footprint and be heavier which can require roof infrastructure reinforcement.

O&M

- Over a 12-month period, maintenance requirements for the challenge unit were similar to that of the baseline standard unit.

Deployment

- End-of-life, new construction
- Product tested: Daikin/Rebel

Testbed Energy Savings

26% compared to code-compliant

Testbed Cost Effectiveness

Payback compared to code-compliant: 3.4

SIR: 4.4

Incremental costs compared to code-compliant: $6,000 (7.5 Ton unit)

Tech life: 15

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2016

Honeycomb Solar Thermal Collector

027

Best suited for central hot water systems with electric heating and large uniform loads.

Description & Lessons Learned

- Solar thermal collector that uses a honeycomb insulating layer to minimize heat loss.
- Not more efficient in cold climates for standard DHW. In SHW systems without a storage tank, HSTC should outperform other flat plates, particularly in cold climates.
- Life-cycle cost, rather than efficiency, should drive system selection.
- Trained SHW installer is critical to address unique SHW features.

Installation

- Implement water and energy efficiency measures before sizing a solar thermal system.
- Use a trained solar hot water installer familiar with features of SHW systems.

O&M

- $100/year maintenance.
- Overheating protection may reduce damage to collector components, decreasing lifetime maintenance costs.

Deployment

- Retrofit
- Product tested: Tigi Solar, Honeycomb collector

Testbed Energy Savings

11,100 kWh/year water heating energy savings

Testbed Cost Effectiveness

Payback: <10 years

SIR: 1+

Installed cost: $17,916 @ avg. cost of $102/ft²

Tech life: 25 years

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Wood-Pellet Biomass Boilers

Best suited for facilities in cold climates that use fuel oil and are located within 50 miles of a biomass pellet mill.

Description & Lessons Learned

- Biomass boilers use a fully-automated auger system, similar to those used for conveying feed and grain on farms, to deliver pellets from an outdoor silo to the boiler's hopper.
- Boilers can use locally sourced renewable energy including waste wood, some of which has been accumulating in forests in the western U.S. due to the pine-beetle infestation.
- Recommended for consideration in hot-water facilities using fuel oil, in northern climates within 50 miles of a biomass pellet mill.
- Payback is dependent on difference between biomass fuel costs and heating oil costs. Proper boiler sizing is critical.

Installation

- Turnkey installation for existing buildings.
- Assess available facility space for installing biomass system, including pellet storage, re: whether need to construct additional building space.
- Design system to meet 60% of peak load.

O&M

- Automated monitoring and control systems run all aspects of the boiler, including feed, load reduction, and tube cleaning, and continuously adapt as system conditions change.
- Fuel handling is straightforward, given the uniformity of pellets.
- Operational stability enables small-scale operations with small maintenance support teams, thus reducing labor costs.

Deployment

- End-of-life
- Product tested: Advanced Climate Technologies, Bioenergy Boiler

Testbed Energy Savings

85.6% heating energy efficiency at a 45% partial load. Increased loads will increase efficiency.

Testbed Cost Effectiveness

Payback: 3 years, assuming 4,000,000 BTU boiler, $300/ton pellets vs.$3.63/gallon diesel, 75% capacity

SIR: 9.6

Cost:

1,000,000 BTU = $260,000

4,000,000 BTU = $640,195

Average fuel cost $169/ton

Transportation .15 per ton mile

Tech life: 30 years

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